DEALING WITH STRATIFICATION WITHIN A WATER SUPPLY RESERVOIR

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ABSTRACT

Dealing with stratification within water supply reservoirs is a common problem for urban water authorities. Failure to identify and control stratification can compromise water treatment operations, meeting regulatory standards, customer expectations, environmental flow releases and potentially isolate an affected reservoir from a supply system.

In recent years, CHW field staff have undertaken stratification monitoring to identify the early onset of stratification and developed operational response procedures that introduce appropriate control measures to avoid potential impacts and minimise any adverse affects.

This paper discusses:

- Stratification within reservoirs and the associated problems for urban water authorities;
- The importance of developing a stratification monitoring program and understanding seasonal water quality characteristics within the profile of a reservoir; and
- The introduction of aeration as a stratification control measure.

KEY WORDS

Stratification, Water quality, Reservoir profile, Monitoring, Aeration, Water treatment.

1.0 INTRODUCTION

The development of layers within the profile of a water body that results in sudden changes in water quality is known as stratification. Without intervention, the severity of stratification commonly increases, along with the possibility of drawing poor quality water from a storage reservoir. Hence, water treatment processes and water resource operations can potentially become complicated and difficult to manage.

In recent years, CHW field operators have undertaken regular monitoring and analysis of results to gain a better understanding of seasonal changes within the profile of CHW reservoirs. In turn, the analysis of stratification monitoring results has facilitated the timely seasonal use of aeration in reservoirs operated and managed by CHW. Aeration not only introduces oxygen into a water body, but also facilitates movement and mixing to help counteract the severity of stratification.

This report largely focuses on the development of CHW's stratification monitoring program across all supply reservoirs, and specifically looks at the effectiveness of applying aeration to Musical Gully Reservoir.

Musical Gully is relatively small reservoir with a capacity of 228 megalitres (ML) that supplies the township of Beaufort in western Victoria. The monitoring results obtained from Musical Gully provide some valuable insights into stratification trends and the effectiveness of using aeration to help prevent severe stratification.

2.0 DISCUSSION

2.1 Basic Characteristics Of Stratification

The figure below provides a schematic of a water supply reservoir and some of the key characteristics that are typical of a severely stratified water body.

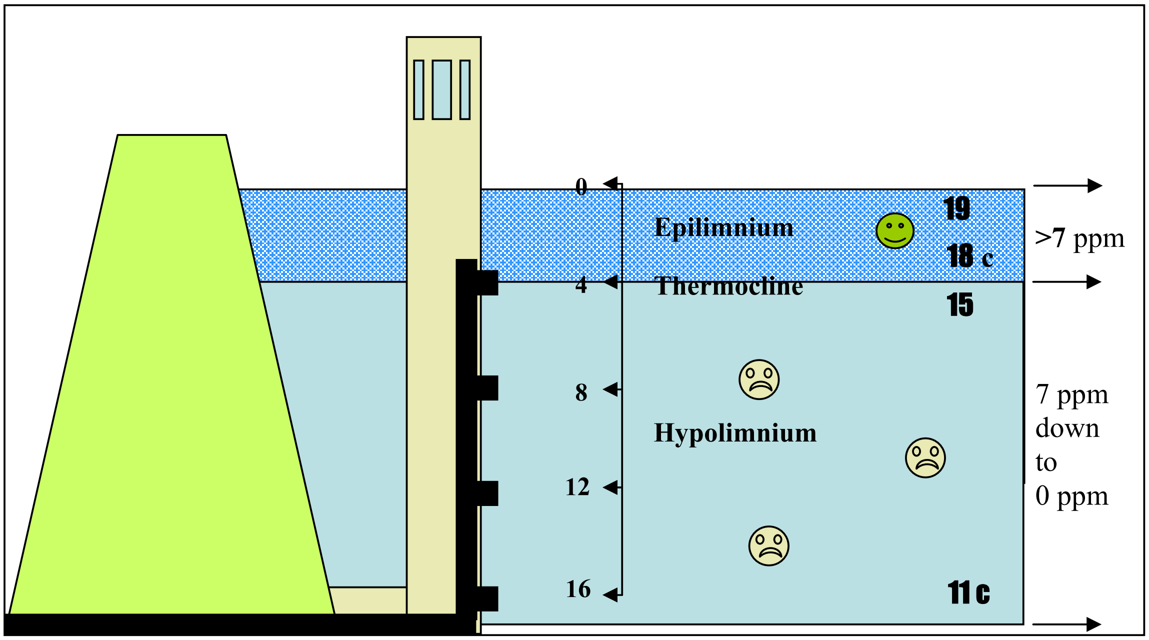

Figure 1: ***Schematic Of A Severely Stratified Water Supply Reservoir***

Some of the most important features of a severely stratified reservoir are the following.

- A layer of aerobic water, near the surface, known as the epilimnium, that is relatively warm and high in dissolved oxygen (commonly above 7 ppm). In this zone, temperature and dissolved oxygen levels tend to be maintained by the penetration of sunlight and mixing created by wind.
- A layer of water, known as the hypolimnium, that is commonly anaerobic, extends from the bottom of the reservoir and is relatively cool and low in dissolved oxygen (commonly below 3 ppm).
- A very thin layer of water, known as the thermocline, where a rapid change in temperature and dissolved oxygen occurs in between the epilimnium and hypolimnium.
- Stratification becomes more severe during warmer months of the year when the intensity and duration of sunlight increases, and mixing from reservoir inflow decreases due to reductions in streamflow. As the severity of stratification increases, the contrast in water temperature and dissolved oxygen between the epilimnium and hypolimnium tends to become more pronounced, and the position of the thermocline tends to rise, effectively increasing the proportion of the hypolimnium.

2.2 Potential Effects Of Stratification On Urban Water Authorities

One of the common causes of problems to water resource operations is that the thermocline rises above the designated offtake level and water of poor quality is drawn from the reservoir.

Failing to undertake adequate monitoring and developing an ongoing understanding of water quality characteristics within the profile of a reservoir can create considerable risks and problems for urban water authorities. Some of the most common problems that can be associated with reservoir stratification are outlined below:

- Water treatment processes can become difficult to manage and the cost of treatment can increase substantially.
- The ability to meet regulatory standards in regard to drinking water quality can become compromised.
- Water odour can become a problem, particularly as a result of the release of hydrogen sulphide.
- Manganese and iron particles can become prevalent in anaerobic water. If these particles are not detected during treatment, clothing items can become stained during washing as these particles react with the oxygen particles in washing detergent.
- The likelihood of receiving customer complaints can increase.
- Environmental flow releases can become jeopardised as the release of cold or anaerobic water can have adverse impacts on downstream river health or other beneficial users.
- Adverse affects on the ecosystem within the reservoir can occur as a result of the formation of minerals due to low dissolved oxygen levels, potential impacts on aquatic life such as fish kills, and the potential for algal blooms to occur may also increase.
- In extreme cases, a severely stratified reservoir may potentially need to be isolated from a water supply system due to poor water quality.

2.3 Developing An Effective Monitoring Program

Developing an effective monitoring program and undertaking relatively simple analysis of results serves as an effective tool to facilitate a strong understanding of changes to reservoir profile characteristics throughout the duration of each year.

The key to the development of any monitoring program is the ability to identify the level of data collection required to achieve adequate analysis of results, whilst considering the available resources, funding and level of training required.

In recent years, CHW have developed a basic, but effective monitoring program where field staff collect and analyse important reservoir profile data on a routine basis to help improve reservoir management. Some of the key features during the development of CHW's reservoir profiling monitoring program included the following:

- Starting with a basic, but flexible monitoring program to enable fine tuning over time.
- Investigation and purchase of an appropriate dissolved oxygen and temperature sensor. Features that were considered most important included repeatability of results, ease of use and calibration, durability, hand-held unit, lengthy cable, water resistance, ability to log data, and adequate technical support for staff training and repairs.
- Considering availability of resources such as boating equipment, trailers, vehicles, safety equipment, level of staff knowledge and training.
- Allocating a designated day for field parties to specifically undertake reservoir profiling.
- Selection of reservoirs for inclusion in the monitoring program and identification of a specific location within each reservoir for monitoring.

- Commencing with monthly monitoring at all selected reservoirs to identify seasonal trends in reservoir profile characteristics.
- Obtaining readings at depth intervals of one metre within the profile of the reservoir.
- Adjusting the monitoring interval at specific reservoirs over time to facilitate more detailed information (i.e. fortnightly or weekly monitoring may be beneficial when stratification is likely to become more severe).
- Developing and maintaining adequate computer files to easily store and analyse monitoring data, and training field staff to use the files with skill and confidence.
- Developing a reporting system to ensure that any abnormalities, trends or changes in reservoir profile are quickly reported to the co-ordinator.

Over the past few years, CHW field staff have shown that they can conduct all aspects of the monitoring program with great success. The field staff involved with the monitoring program have developed important field monitoring and data collection skills, greatly increased their knowledge of trends in reservoir profile, and displayed that they can detect the early onset of stratification.

<u>Figure 2:</u> ***A Hand-Held Dissolved Oxygen Meter***

2.4 Introducing stratification control measures

When monitoring conducted by field staff has detected the onset of stratification, CHW have introduced the use of aeration as a control measure in some reservoirs. The effectiveness of aeration appears to depend on the size of reservoir and the extent of aeration.

In recent years, CHW have used both electrical blowers (permanent installations) and diesel fuelled air compressors (temporary installations) to aerate reservoirs. Use of these relatively simple items of machinery appears to be quite effective in relatively small reservoirs.

For example, Musical Gully Reservoir has a full supply capacity of 228 ML, and the use of an air compressor has proven to be successful in keeping the thermocline at depths that are safely below the upper off-take level.

The following figure depicts the change in dissolved oxygen levels in relation to the off-take levels of Musical Gully Reservoir as the 2005-06 water season progressed from winter through to spring.

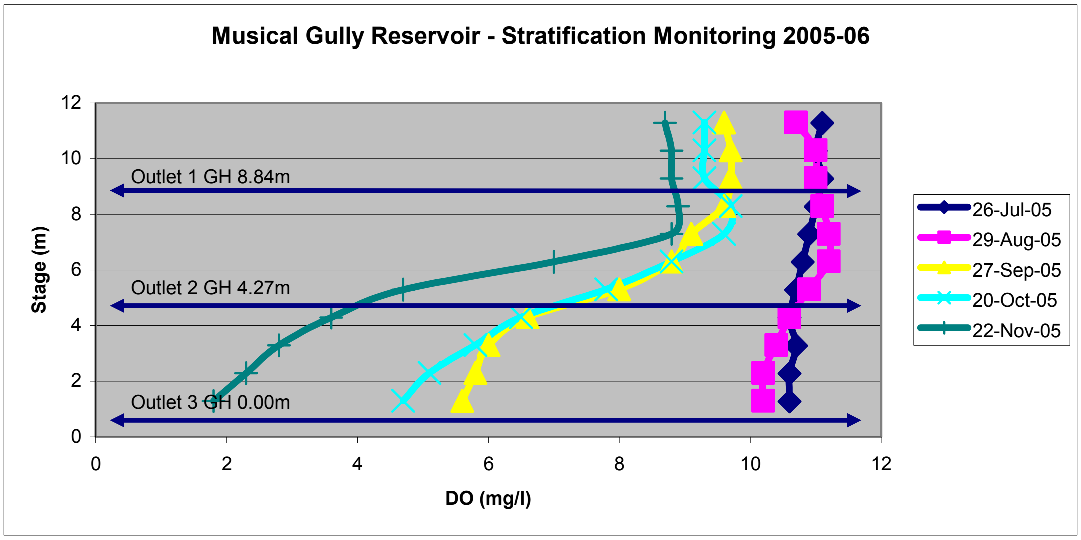

Figure 3: ***Dissolved Oxygen Profile At Musical Gully Reservoir, Winter/Spring 2005***

The key feature of the figure above (Figure 3) is the onset of stratification by late spring and potential for water that is low in oxygen to near the upper off-take outlet (Outlet 1) if stratification was to become more severe during summer. After the 22nd November 2005, aeration was introduced to Musical Gully Reservoir to attempt to prevent the thermocline from approaching Outlet 1. The figure below (Figure 4) depicts the dissolved oxygen profile throughout the summer of 2005-06 with the aerator in use.

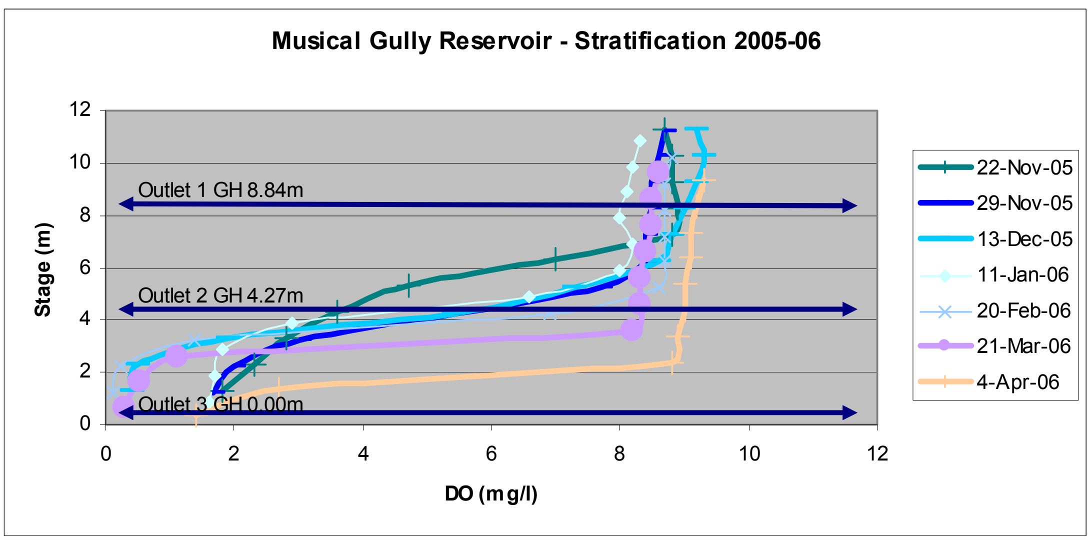

Figure 4: ***Dissolved Oxygen Profile At Musical Gully Reservoir, Summer 2005-06***

The key features of the figure above (Figure 4) are the immediate lowering of the thermocline after the introduction of aeration on the 23rd November 2005 (indicated by comparison of the dissolved oxygen profiles taken on the 22nd November and 29th November 2005), and the ability of aeration to keep the depth of the thermocline down throughout the summer.

The combination of collecting monitoring data and the use of aeration assisted to provide CHW with a great deal of confidence in regard to the quality of the water that was being drawn from Musical Gully Reservoir throughout the entire water season.

CHW have introduced aeration to other relatively small reservoirs with similar success and are now looking to install more permanent aerators to keep operating costs down.

Figure 5: ***A Portable Air Compressor Installation at Musical Gully Reservoir***

3.0 CONCLUSIONS

Failure to identify and control severe reservoir stratification can pose serious risks to urban water authorities. The majority of field operators and reservoir keepers are not expected to understand the finer detail and complexity of stratification on a water body. However, with adequate training, appropriate equipment and the implementation of a committed monitoring program, CHW field staff have displayed that they can substantially improve reservoir management and operational decision making processes.

Through the regular collection and analysis of monitoring data, field staff can develop an understanding of trends that enables them to:

- understand water quality within the profile of a reservoir in relation off-take levels;
- identify the early onset of more severe stratification, where poor quality water comes closer to the surface of a reservoir;
- adjust water resource operations to avoid drawing or releasing poor quality water; and
- provide timely recommendations for the introduction of stratification control measures.

CHW's monitoring results indicate that the use of aeration in relatively small reservoirs has helped to prevent the stratification layer from rising during summer months. As such, aeration has proven to be an adequate stratification control measure in certain reservoirs and has provided some important benefits including risk minimisation, greater confidence in water treatment processes, enhanced water quality management, and improved efficiency in reservoir management.

4.0 ACKNOWLEDGEMENTS

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